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CONSUMPTIVE USE IN THE RIO GRANDE BASIN

By Robert L. Lowry, M. ASCE

IRRIGATION DIVISION

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AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS

CONSUMPTIVE USE IN THE RIO GRANDE BASIN

By Robert L. Lowry,[1] M. ASCE

Synopsis

The necessity of controlling the consumptive use of water in the irrigated sections of the Rio Grande is a problem of national interest. The beneficial use of water in this river basin has increased in recent years only through control of nonbeneficial uses and careful husbanding of all available supplies.

The case of the El Paso (Tex.)-Juárez (Mexico) section of the Rio Grande Valley is presented to illustrate the proportion of available water that was lost because of the natural channel conditions and to indicate the method used in reducing these losses. The manner in which the consumptive use was determined is shown in detail. The effect of river control is analyzed, and recommendations are made for the planning of similar projects.

Introduction

With the waters of southwestern streams of the United States almost wholly appropriated for irrigation development, it is urgent that users be made to realize that the major opportunity for further expansion in irrigation rests in the possibility of converting nonbeneficial consumptive uses to beneficial purposes. The nonbeneficial uses in some areas are exacting a heavy toll of water and consist largely of the water demands of native vegetation plus losses incident to evaporation from swamps and badly deteriorated stream channels. In many places the areas covered by native vegetation that are using water directly from the streams are increasing, and natural channels are rapidly deteriorating as the result of sedimentation. The Rio Grande is no exception to the general rule. Any further expansion in irrigation in the Rio Grande Basin upstream from Fort Quitman, Tex., will probably have to come through what now seems the one remaining opportunity to provide

Note.—Written comments are invited for publication; the last discussion should be submitted by May 1, 1952.

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additional water—a reduction in the natural losses. Most of the available water supply for the Rio Grande in this upper reach is now regulated by reservoirs that furnish water for practically full irrigation development. The problem of water use and control in the Rio Grande Basin has become a matter of national concern.[2]

Control of Consumptive Use

Reservoir Development.—Many reservoirs have been constructed throughout the Rio Grande Basin to provide irrigation water. These reservoirs have a combined storage capacity of more than 8,100,000 acre-ft. International reservoirs on the main river, downstream from Fort Quitman, now under construction or actively contemplated[3] (1950), will add another 8,500,000 acre-ft of storage capacity. These reservoirs provide a controlled water supply for the irrigation of more than 2,500,000 acres of land, of which about 1,780,000 acres are in the United States, with the remaining 720,000 acres in Mexico.

Losses Through Nonbeneficial Consumptive Use.—In the Rio Grande Basin the most notable example of stream depletion by nonbeneficial consumptive use, for which there is some hope of relief through remedial measures, is that of the area of more than 15,000 acres at the head of Lake McMillan, on the Pecos River in N. Mex., now covered by a dense growth of salt cedars. A plan of the Bureau of Reclamation (USBR), United States Department of the Interior, for bypassing this area with a side channel has been developed with the expectation that an annual saving of from 30,000 to 40,000 acre-ft of water may be realized.

Another area in which nonbeneficial uses are large is the Middle Rio Grande Basin in N. Mex. A project to bring about improvement of this condition by channel rectification has been jointly submitted to Congress by the USBR and the Corps of Engineers, United States Army. When consummated, it is expected that a substantial saving in water in that area will result.

El Paso-Juárez Valley Study

Basis of Studies.—An example of what can be accomplished by the conversion of nonbeneficial uses to beneficial uses is afforded by the records for the El Paso-Juárez Valley of the Rio Grande. Soon after 1900 there began a steady expansion of the irrigated area of this valley without any appreciable change in the water supply. This continued expansion has been made possible by a marked decrease in the natural losses between El Paso and Fort Quitman.

Data on inflow and outflow for this reach of the river have been assembled and are shown in Table 1. The determination of these natural losses was made as the result of an inflow-outflow study covering the 49-yr period from 1900 to 1948. Most of the inflow to the area (Col. 9) is measured in the river at the El Paso gaging station, which has been in operation since 1889. A minor quantity, contributed by the normally dry arroyos between El Paso and Fort Quitman, was estimated from the records by the Hydrographic Office of

[2] "Ten Rivers in America's Future," The Report of the President's Water Resources Policy Commission, Vol. 2, U. S. Govt. Printing Office, Washington, D. C., 1950.

[3] "Falcon Dam Stimulates Irrigation in Mexico," by J. C. Bustamante, *Civil Engineering*, May, 1951, p. 273.

the United States Section of the International Boundary and Water Commission (IBWC). The outflow from the area (Col. 10) has been measured since 1924 at the Fort Quitman gage. Estimates for the period 1900 through 1923 were based largely on the records at El Paso and the Upper Presidio, Tex., gage. The difference between the inflow and outflow represents the total

TABLE 1.—STREAM DEPLETION IN THE EL PASO-JUÁREZ VALLEY OF THE RIO GRANDE

Year	Irrigated area (acres)[a]	Unit consumptive use[b] (acre feet per acre)	Effective rainfall[c] (feet)	Unit stream depletion[d] (feet)	Stream Depletion in Thousands of Acre Feet			River Flow in Thousands of Acre Feet	
					Irrigation only[e]	Total[f]	Channel[g] loss	Inflow[h]	Outflow[a] at Ft. Quitman
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1900	10,000	3.27	0.80	2.47	24.7	105.6	80.9	188.1	82.5
1901	12,000	3.26	0.66	2.60	31.2	201.4	170.2	373.1	171.7
1902	6,000	3.27	0.87	2.40	14.4	41.5	27.1	72.2	30.7
1903	8,000	3.16	0.83	2.33	18.6	398.4	379.8	1,048.8	650.4
1904	500	3.19	0.93	2.26	1.1	180.9	179.8	492.8	311.9
1905	9,000	3.15	1.13	2.02	18.2	491.6	473.4	2,041.8	1,550.2
1906	12,000	3.20	1.02	2.18	26.1	299.6	273.5	1,131.7	832.1
1907	14,500	3.33	0.73	2.60	37.7	325.0	287.3	1,855.9	1,530.9
1908	26,000	3.17	0.65	2.52	65.5	184.9	119.4	479.0	294.1
1909	40,000	3.20	0.53	2.67	106.8	303.9	197.1	880.9	577.0
1910	44,000	3.40[i]	0.29[i]	3.11[i]	116.8[i]	127.9	11.1	583.8	455.9
1911	45,000	3.26	1.10	2.16	97.2	494.1	396.9	1,575.6	1,081.5
1912	47,000	3.07	0.79	2.28	107.2	307.4	200.2	1,377.8	1,070.4
1913	33,000	3.07	0.69	2.38	78.5	155.7	77.2	309.7	154.0
1914	35,000	3.18	1.42	1.76	61.6	340.8	279.2	1,090.3	749.5
1915	38,000	3.13	0.87	2.26	85.9	351.3	265.4	727.2	375.9
1916	42,000	3.30	0.59	2.71	113.8	303.6	189.8	555.4	251.8
1917	45,000	3.22	0.51	2.71	122.0	404.7	282.7	899.2	494.5
1918	49,000	3.14	0.80	2.34	114.6	181.1	66.5	363.3	182.2
1919	52,700	3.17	0.90	2.27	119.6	275.4	155.8	537.7	262.3
1920	57,500	3.23	0.55	2.68	154.1	385.1	231.0	705.7	320.6
1921	62,300	3.30	0.67	2.63	163.8	423.6	259.8	875.7	452.1
1922	67,000	3.25	0.36	2.89	193.6	423.2	229.6	780.6	357.4
1923	71,800	3.18	0.76	2.42	173.8	401.5	227.7	733.9	332.4
1924	76,584	3.24	0.56	2.68	205.2	445.5	240.3	819.3	373.8
1925	90,411	3.27	0.67	2.60	235.1	377.8	142.7	645.7	267.9
1926	94,021	3.22	0.99	2.23	209.7	304.0	94.3	580.3	276.3
1927	95,137	3.36	0.56	2.80	266.4	382.2	115.8	623.1	240.9
1928	105,746	3.26	0.73	2.53	267.5	374.4	106.9	638.2	263.8
1929	108,877	3.20	0.84	2.36	256.9	351.0	94.1	562.8	211.8
1930	108,750	3.27	0.47	2.80	304.5	347.7	43.2	535.7	188.0
1931	107,300	3.29	0.86	2.43	260.7	321.1	60.4	532.7	211.6
1932	99,077	3.23	0.73	2.50	247.7	372.0	124.3	583.1	211.1
1933	101,662	3.32	0.51	2.81	285.7	395.5	109.8	609.3	213.8
1934	98,558	3.48	0.31	3.17	312.4	407.5	95.1	509.9	102.4
1935	98,991	3.30	0.53	2.77	274.2	319.3	45.1	464.7	145.4
1936	99,227	3.29	0.77	2.52	250.1	326.8	76.7	476.4	149.6
1937	108,334	3.34	0.62	2.72	294.6	368.9	74.3	547.2	178.3
1938	110,430	3.31	0.77	2.54	280.5	303.4	22.9	579.6	276.2
1939	111,054	3.31	0.51	2.80	311.0	366.0	55.0	518.2	152.2
1940	114,989	3.29	0.59	2.70	310.5	337.2	26.7	461.5	124.3
1941	118,104	3.25	1.44	1.81	213.7	222.1	8.4	552.6	330.5
1942	119,514	3.31[i]	0.76[i]	2.55[i]	271.6[i]	291.6[i]	20.0[i]	1,562.0	1,270.4[i]
1943	121,102	3.25	0.56	2.69	325.8	401.1	75.3	634.4	233.3
1944	120,346	3.16	0.87	2.29	275.6	353.5	77.9	626.4	272.9
1945	123,203	3.25	0.58	2.67	329.0	368.5	39.5	576.2	207.7
1946	126,290	3.26	0.68	2.58	325.8	374.6	48.8	506.0	131.4
1947	122,891	3.32	0.59	2.73	335.5	368.9	33.4	459.7	90.8
1948	123,650	3.36	0.52	2.84	351.2	358.4	7.2	435.8	77.4

[a] From the records of the International Boundary and Water Commission (IBWC). [b] Based on the average annual temperature in the valley. [c] 85% of the average annual rainfall in the valley. [d] Col. 3 minus Col. 4. [e] Col. 2 times Col. 5. [f] Col. 9 minus Col. 10. [g] Col. 7 minus Col. 6. [h] Inflow at El Paso gaging station plus arroyo inflow as estimated by IBWC. [i] Arbitrarily adjusted to avoid negative figures.

stream depletion or that quantity of water lost from the river within this area (Col. 7). Obviously, this total stream depletion includes the uses of water by irrigated crops, as well as the natural losses. Losses of water by evaporation from the surface of the stream or from open water in swamped areas have been included with the natural losses. In order to reduce this total depletion to its component parts (use by irrigation and natural losses) it was necessary to make estimates of the consumptive use on the irrigated area. Each year since 1900 the area listed as irrigated (Col. 2), including the lands in both the United States and Mexico, was based on information obtained from the El Paso Office of the USBR and the Mexican Section of the IBWC. Unit consumptive use was determined from the relation established by a number of inflow-outflow studies[4] as indicated in Table 2. Temperatures were taken from the records

TABLE 2.—Relation Between Consumptive Use and Mean Annual Temperature

Station or area	State	Consumptive use (feet)	Mean annual temperature (degrees farenheit)	Source
(a) Observed Data				
Wagon Wheel Gap	Colorado	1.30	33.0	United States Weather Bureau
Uncompahgre	Colorado	2.28	50.4	Colorado Water Conservation Board
San Jacinto River	Texas	3.19	68.3	Bureau of Reclamation[a]
Carlsbad Project	New Mexico	2.94	63.6	Bureau of Reclamation[a]
Messilla Valley	New Mexico-Texas	2.83	59.7	Bureau of Reclamation[a]
Lower Rio Grande Valley	Texas-Mexico	3.80	73.8	J. L. Burkholder[b]
Cypress Creek	Texas	3.02	65.6	Bureau of Reclamation[a]
East Fork of Trinity River	Texas	2.82	65.0	Bureau of Reclamation[a]
(b) Determined from Effective Heat Units[c]				
Presidio	Texas	3.42	68.3	....
Eagle Pass	Texas	3.50	71.3	....
Del Rio	Texas	3.30	69.4	....
El Paso	Texas	2.91	63.7	....
Laredo	Texas	3.76	73.0	....
Substation 14	Texas	2.82	65.4	....
Fort Stockton	Texas	2.94	66.2	....
Falfurrias	Texas	3.63	73.2	....

[a] "Consumptive Use of Water for Agriculture," by R. L. Lowry, Jr., and A. F. Johnson, *Transactions*, ASCE, Vol. 107, 1942, p. 1243. [b] *Ibid.*, p. 1287. [c] *Ibid.*, p. 1252.

of the Weather Bureau at El Paso. These temperatures have been modified for the period since the Weather Bureau station was moved from downtown El Paso to the municipal airport, 7 miles northeast of the city. Rainfall records used include both Weather Bureau and IBWC data. Only 85% of the total rainfall each year was considered as effective in order to prevent a duplication in the calculations of runoff. Then, by calculating the total water used by irrigation and deducting that quantity from the total depletion, the depletion by natural causes (called nonbeneficial uses) was left as the residual. The

[4] "Consumptive Use of Water for Agriculture," by R. L. Lowry, Jr., and A. F. Johnson, *Transactions*, ASCE, Vol. 107, 1942, p. 1243.

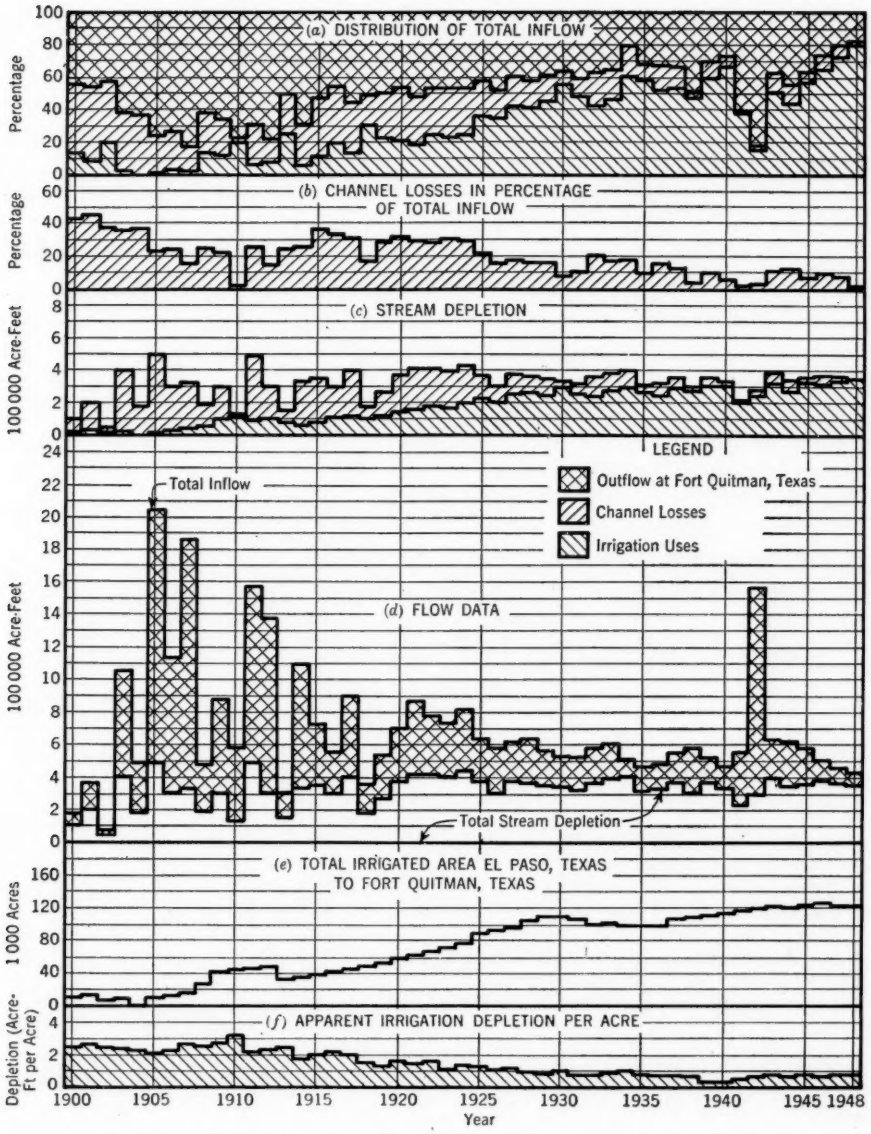

FIG. 1.—STREAM DEPLETION DATA IN THE EL PASO-JUÁREZ VALLEY OF THE RIO GRANDE

different elements of the calculation have been plotted in Fig. 1, which is self-explanatory. The lowest section of the figure shows the depletion caused by irrigation, assuming natural channel losses remained as they were prior to placing control on the river.

Analysis of Results.—Fig. 1 is significant in that it emphasizes the following:

1. The steady expansion in irrigation from 10,000 acres in 1900 to more than 120,000 acres in 1948. The drop in acreage in 1902–1904 was caused by severe drought conditions on the river;
2. The more-or-less constant inflow to the area since Elephant Butte Reservoir started storing water in 1915; and
3. The constantly decreasing channel losses or nonbeneficial uses.

Irrigation uses that amounted to 25,000 acre-ft in 1900 have increased to as high as 350,000 acre-ft in 1948. Within the period the average annual inflow has been decreasing, as indicated by Table 3. Channel losses, which were practically the same during the early half of the period, have declined rapidly since 1924. Although less and less water is being released for irrigation, the acreage irrigated continues to increase. This expansion is being accomplished by the conversion of what were previously natural losses to beneficial use.

Several factors that have resulted in a saving of water have contributed to this conversion from nonbeneficial to beneficial uses. Prior to 1915 the river was uncontrolled. A major portion of the total runoff in the Rio Grande at El Paso came as floods in the form of snow-melt from the headwaters area. This situation resulted in the usual spring highwater, followed by long periods of low flow. In the years when high spring floods occurred, the banks were overtopped, and wide areas of swamp land were submerged, with consequent high natural losses. Conversely, in years of small spring floods and no overflow, natural losses were relatively low. Since two drought periods (1902–1904 and 1910–1913) occurred between 1900 and 1914, the average channel losses were somewhat lower than might be expected for the 14 years.

TABLE 3.—Inflow and Channel Loss—El Paso-Juárez Valley

Period	Length of period	Average Annual Quantity in Acre-Feet	
		Inflow	Natural channel losses
1900–1914	15	900,000	210,000
1915–1924	10	700,000	215,000
1925–1937	13	562,000	91,000
1938–1948	10	535,000[a]	39,500

[a] Exclusive of 1942 when approximately 1,000,000 acre-ft were spilled from Elephant Butte Reservoir.

Since the beginning of storage in Elephant Butte Reservoir (in 1915) the river control through this section has regulated the annual snow-melt floods. Lands that had previously been swamped, however, continued as heavy water users, and the need for drainage at an early stage in the project became of paramount importance. A drainage program initiated in 1917 was virtually

completed by the end of 1924, and the irrigated area practically doubled within this period.

The next 13-yr period (1925 through 1937) was marked by further irrigation expansion accompanied by a great decline in the natural losses. Irrigation increased rapidly until an average of more than 100,000 acres of irrigated land was reached. Natural losses averaged only 42% of the average that prevailed during the preceding period, and as the area became more fully developed the natural losses were more nearly confined to the limits of the channel itself.

By the end of 1937, the channel rectification through the El Paso-Juárez Valley was practically completed by the IBWC and resulted in a further reduction in the natural losses. The rectification project produced a straightening and shortening of the river channel between El Paso and Fort Quitman, reducing the channel length from 155 miles to approximately 88 miles. Data for the 11-yr period (1937–1948) show a still further expansion in irrigated area, to average about 119,000 acres during the period. This increase of 19,000 acres over the previous period was made possible by a reduction in the natural losses from an average of 91,000 acre-ft per yr to 39,500 acre-ft per yr.

TABLE 4

Period	Average irrigated area (acres)	Average Annual Quantities in Acre-Feet		
		Total depletions	Depletions due to irrigation	Outflow at Fort Quitman
1900–1914	22,400	263,600	53,700	637,000
1915–1924	56,200	359,500	144,600	340,300
1925–1937	101,000	357,500	266,500	204,600
1938–1948	119,200	345,400[a]	305,900	189,700[a]

[a] Exclusive of 1942.

The averages of the remaining elements in the calculations have been summarized in Table 4.

A feature that is noteworthy in Table 4 is that the total depletions of river water have remained practically constant since the river was controlled by Elephant Butte Dam. Within that same interval (1915–1948) the irrigated area has increased from 38,000 acres to more than 120,000 acres.

The procedure that has been so successfully employed in this area can be equally well applied to other areas. It involves one or more of the following three items of construction:

a. Regulation of the river by storage;
b. Channel rectification and improvement; and
c. Drainage and canal lining.

Full development of natural resources in the Southwest cannot be reached, and any further expansion in irrigation is limited until the natural losses have been reduced to an economic minimum.

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